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Report No. 691.1/3
Watertown Arsenal

March 12, 1936

Progress Report I

Heat Treatment of Chromium Plate on Steel

Object

To determine maximum effects of very high temperature heat treatment of chromium plated steel

References

X. O. 48-A14

Letters O.O. 400.111/3854-Fiedler, Marcell, R.I.A. (400.111/102)

O.O. 400.111/3855- " " W. A. (400.111/34)

O.O. 400.111/3079- " " W. A. (400.111/19)

Conclusions

Chromium plate on steel is hard, brittle, and full of cracks which reach to the base metal. Corrosion resistance is poor.

Heat treatment of the chromium plate causes (1) formation of alloys of iron and chromium at the interface, and (2) elimination of cracks with resultant tremendous increase in corrosion resistance of the plated surface,

and (3) softening of the plate with increase in its ductility.

During heat treatment the oxidation of the chromium surface results it its being hardened skin-deep.

Etching with $FeCl_3$ is necessary to reveal the structure of the Cr plate and alloy formation.

The presence of high trivalent Cr content in plating bath inhibits building up thick plates of Cr on steel.

Recommendation

It is recommended that the study be continued, attention being paid to the localized effects of heating by high frequency currents.

Introduction

The adhesion of plate to steel surfaces is of paramount importance in Ordnance which requires corrosion resistant surfaces. It is the experience of the Ordnance Department that complete reliability upon the adhesion of plate to steel subjected to wear, as on piston rods, is not to be had.

Metallurgists are turning to heat treatment in order to improve the performance of plated articles. This Report describes the maximum effects to be had from heat treatment of Chrome plated steel.

Material and Procedure

Soft steel pipe was machined to give a fresh cut steel surface and was then chrome plated under different conditions. The behavior in salt spray and the hardness and microstructure before and after heating to 1100°C for eight hours and furnace cooling were noted.

Results

Figure 1 shows that before heat treatment, chrome plated steel rusted extensively if exposed to the salt spray, whereas, after heat treatment no rust other than that adjacent to cut surfaces was evident.

Figure 2 shows the microstructure of chrome plated steel before and after heat treatment. Before heat treatment, the plate is full of cracks which reach the base metal, but after heat treatment these cracks are absent. Nital etching does not enhance the evidence of the existence of an alloy between steel and chromium after heat treatment over that in the unetched condition. But etching with $FeCl_3$ does reveal the existence of an alloy very plainly, as shown in Figure 3. The hardness as revealed by Bierbaum's microcharacter is also shown. The hardness of Cr plate is lowered from Vicker's Brinell 724 to 139 by diffusion heat treatment. Study revealed the presence of numerous cracks around the Vicker's impression on the hard Chromium plate, and the absence

of these cracks around the Vicker's impression in the heat-treated and softened Chromium plate. This may be taken as an indication of the improvement in ductility of the plate due to heat treatment.

An interesting observation is shown on the bottom print of Figure 3, (ME 428). The surface of the Chromium plate was oxidized: Grain boundaries and old crack lines are filled with a dove gray constituent taken to be an oxide. This must have formed a solid solution with the Chromium for the extreme outside edge is very hard.

Discussion

The presence of trivalent Chromium in the plating bath in amounts over ca. 1 oz/gal. inhibits the building up of thick plate.

The effect of very high sulfate content in the chrome bath was masked by the presence of high trivalent Chromium. Evidently it is not very deleterious. At first it was believed that high sulfate counteracted the effect of high trivalent Chromium, but only, if at all, to the extent of getting a flash of Chromium on the surface.

Rough machined surfaces are plated exceptionally well.

Heat treatment to cause diffusion of the plate into the base metal brings about a tremendous increase in

corrosion resistance. Adherence of the plate to the base metal would also be enhanced. The ductility of the plate is increased by heat treatment.

The hardening of the surface of the plate by oxidizing during heat treatment offers interesting possibilities and, if it can be controlled, would be of value to Ordnance.

Respectfully submitted,

Peter R. Kosting

ELECTRO PLATED
HEAT TREATED

ELECTRO PLATED

CORROSION OF CHROME PLATED STEEL
IN SALT SPRAY

1-16-36 FIG 1 362-82

Chromium Plate on Steel

Steel on bottom; mounting medium on top; Cr plate in middle

FCr1 X1000 Nital Etch ME402

34.0 oz/gal. chromic acid
4 oz/gal. trivalent Cr
3.4 oz/gal. sulfate
3.8 v; 1 amp/sq.in;
102/104°F; 1 hour
Coating: 0.0008" thick, cracked, steel exposed.

FCr2 X1000 Unetched ME405

34.0 oz/gal. chromic acid
4 oz/gal. trivalent Cr
3.4 oz/gal. sulfate
7 v; 3 amp/sq.in;
102/108°F; 1 1/2 hrs.
Coating: 0.0001" thick, cracked, steel exposed.

Steel on bottom: Cr plate on top

FCr5 X1000 Nital Etch ME407

33.4 oz/gal. chromic acid
.4 oz/gal. trivalent Cr
.4 oz/gal. sulfate
5.6 v; 3 amp/sq.in;
108/118°F; 10 3/4 hrs.
Coating: 0.008" thick, cracked, cracks penetrated to steel base.

FCr5H X1000 Unetched ME410

Same as FCr5 only heated to 1150°C, 8 hrs, furnace cooled. Steel diffused into Cr and Cr diffused into steel. Some old cracks oxidized. Diffusion process sealed cracks which penetrated as far as steel before diffusion.

FCr5 X100 Nital Etch ME406

Same as above.

FCr5H X100 Unetched ME409

Same as above.

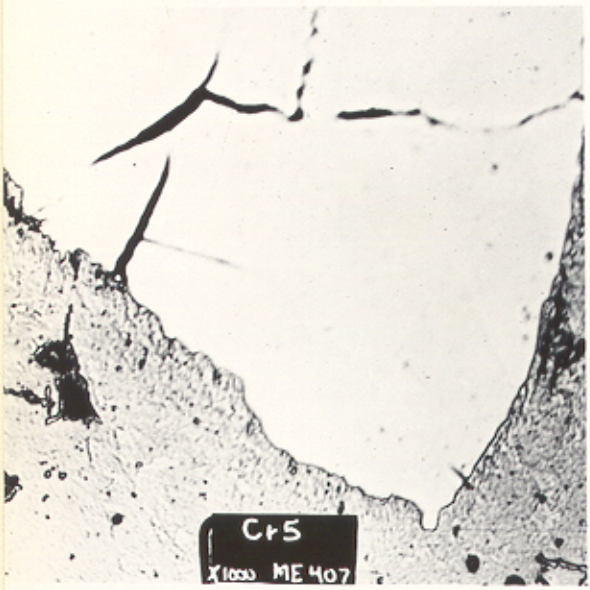
Fig. 2

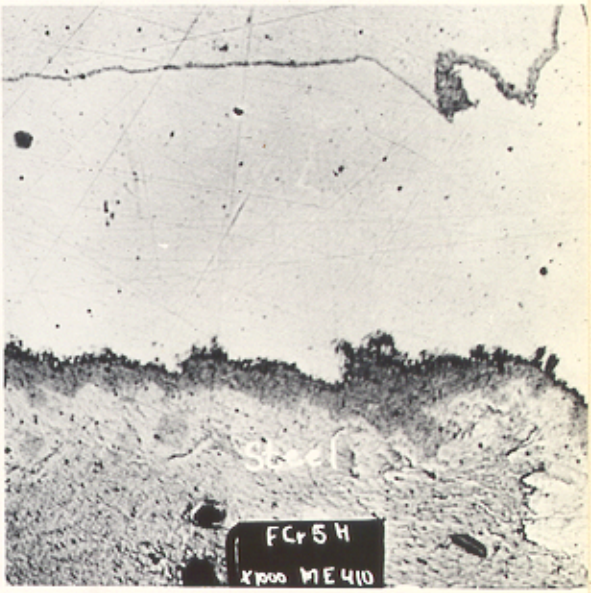
Fig. 3

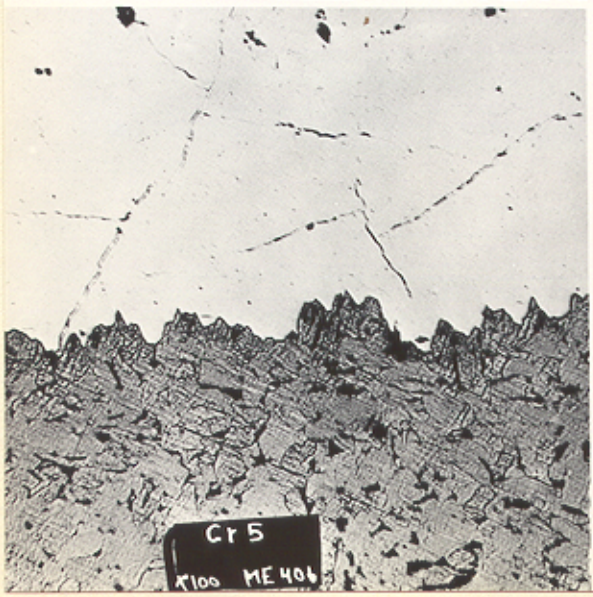
Scratch hardness of Cr Plate on Steel. Bierbaum Microcharacter 3 g. load. $FeCl_3$ etch X500.
Top FCr5 (left) steel base: Vickers Hardness, 10 Kg, 135, (right) Cr plate: Vickers Hardness, 10 Kg, 724
Middle FCr5H, heat treated Cr plate 1150°C, 8 hrs, Furnace cooled. (left) steel base: Vickers Hardness, 10 Kg, 131, (right) Cr plate: Vickers Hardness 139, (middle), hard layer of Fe-Cr alloys.
Bottom Outside edge of FCr5H (left) Oxidized Cr plate at surface is hard. (right) Cr plate further from surface is softer.


FCr1
X1000 ME402


FCr2


Cr5
X1000 ME407


Steel
FCr5H
X1000 ME410


Cr5
X100 ME406

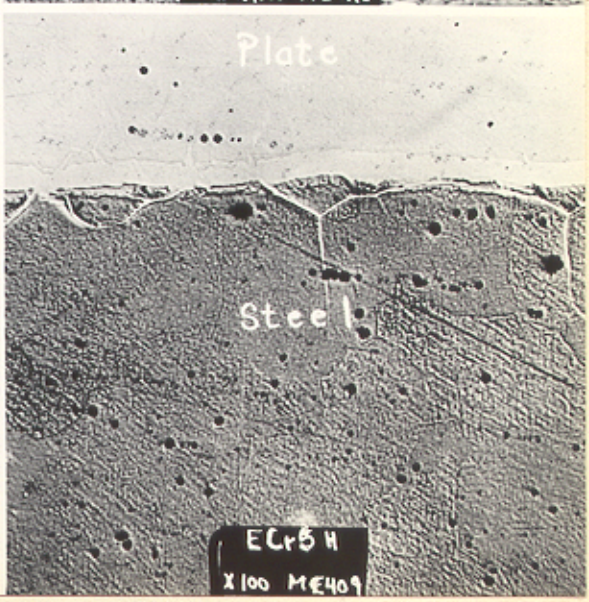
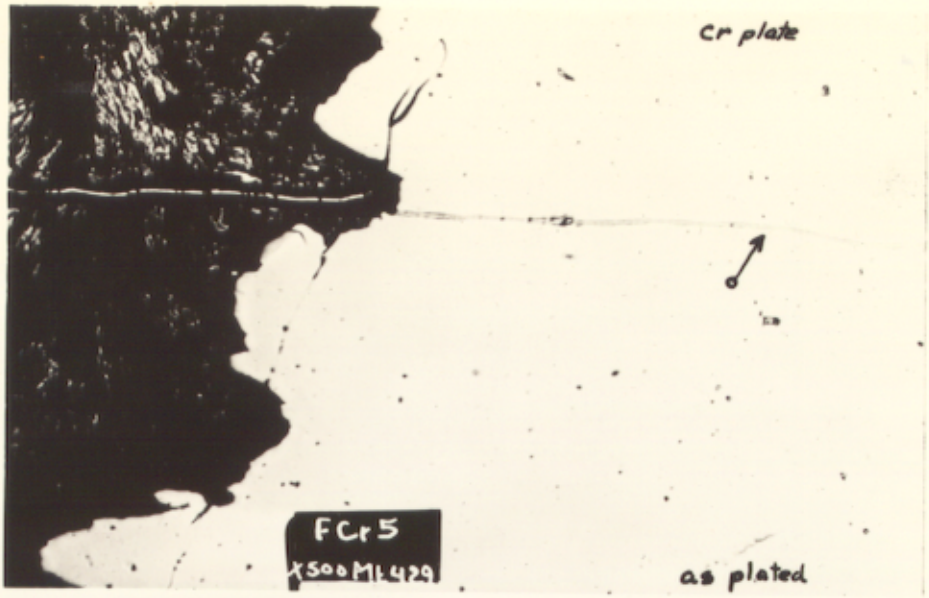
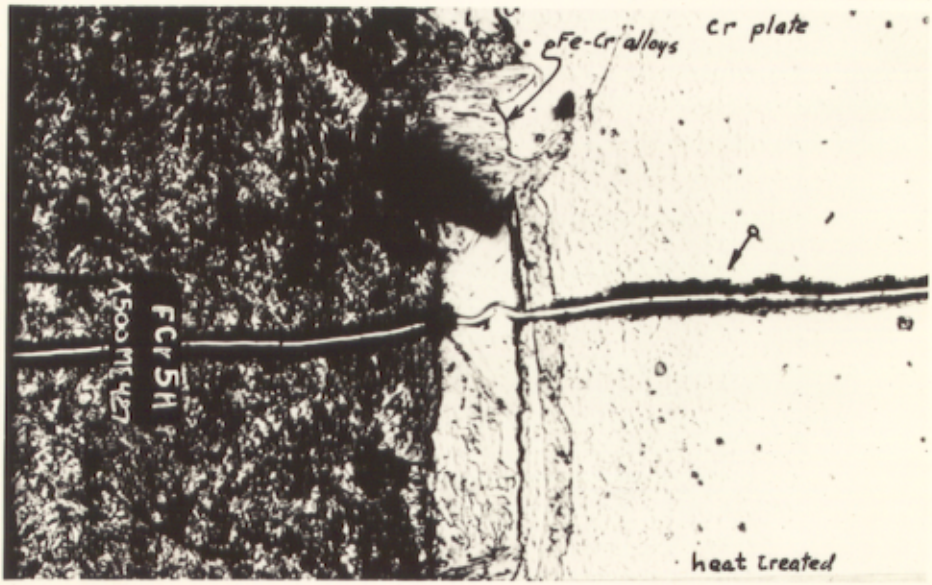


Plate
Steel
ECr5H
X100 ME409


Cr plate
FCr 5
X500 ME429
as plated


Cr plate
Fe-Cr alloys
FCr 5H
X500 ME427
heat treated


outside edge
FCr 5 H
X500 ME428
heat treated